Coastal Ocean Modeling, Data Assimilation and Forecasting

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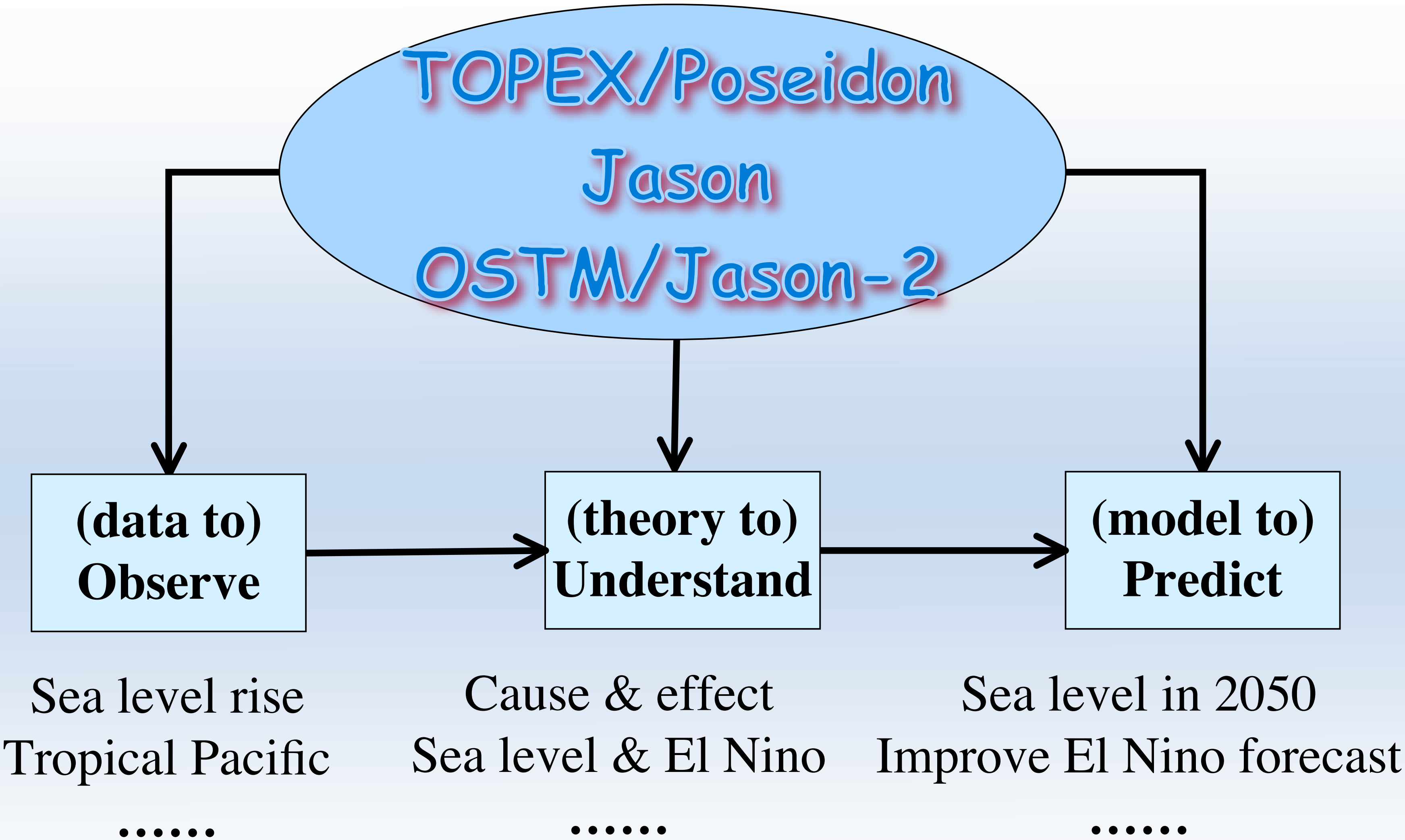
Satellite Altimetry to enable new Science and Applications



A new frontier: Coastal ocean forecasting

Why do we need to forecast the coastal ocean?

- Important
  - Public access: Over 50 percent of the American people live within 50 miles of the ocean
  - Resources: Ocean activities contribute ~$100B and support ~2M jobs
  - Habitats: Over 75 percent of the commercially important fish species
- Needs to observe, understand and ultimately predict
  - The oceans drive weather and climate, so if we understand the oceans better, we should be able to better forecast weather/climate
  - Our nation’s security, environment, and economy all depend on our ability to understand, monitor, manage, and adapt to changes in our oceans and Great Lakes
  - We know little about the oceans, yet they impact us everyday
  - Our planet is changing quickly in ways that will impact everyone, but exactly how remains unclear

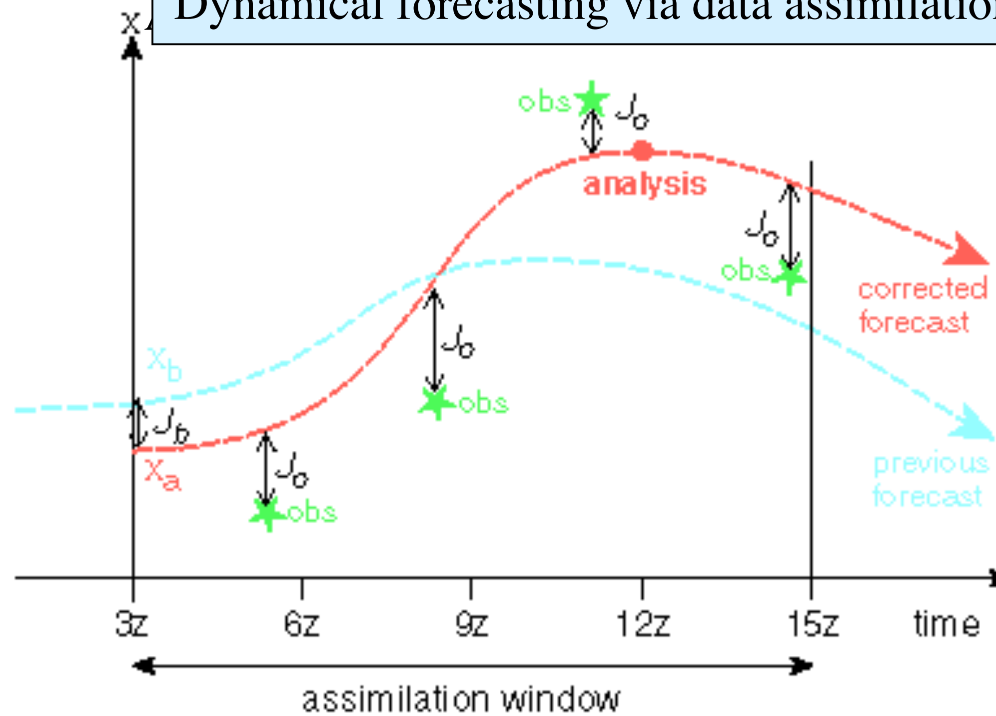
Coastal Ocean Forecasting is similar to Weather Forecasting, but……unique and complex

Gather Observations

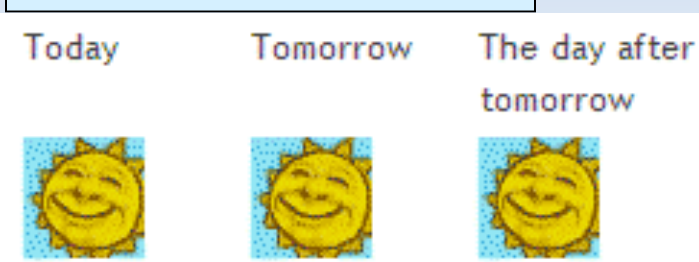
Data Assimilation

Numerical Weather Predictions

Dynamical forecasting via data assimilation



Empirical or statistical forecasting



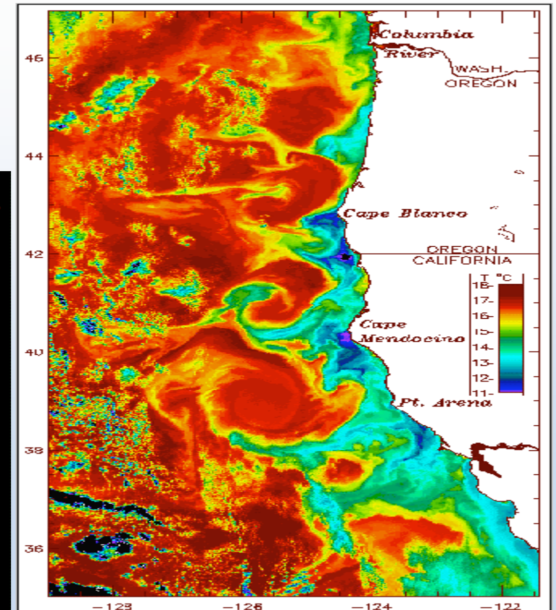
LA Weatherman
Persistent forecast

Forecast Postprocessing

Issue forecasts, Evaluate

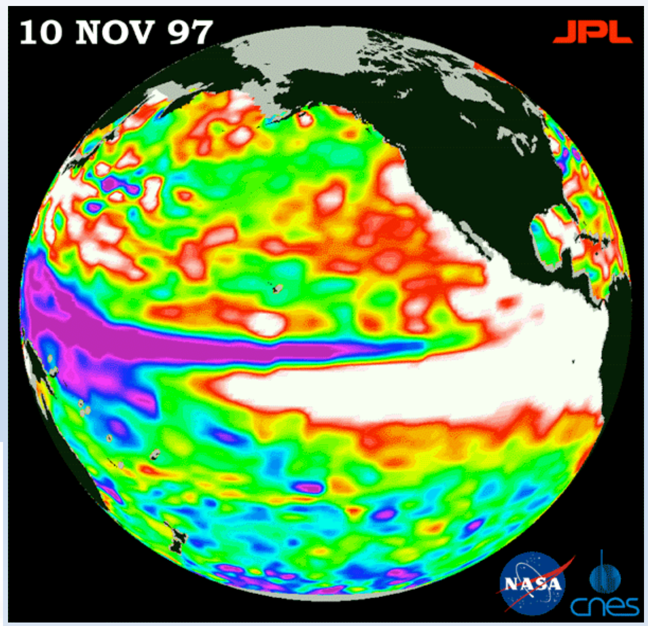
Challenge I: Multi-Scale Coastal Ocean
Coastal, regional to global scales

Eddies and Upwelling



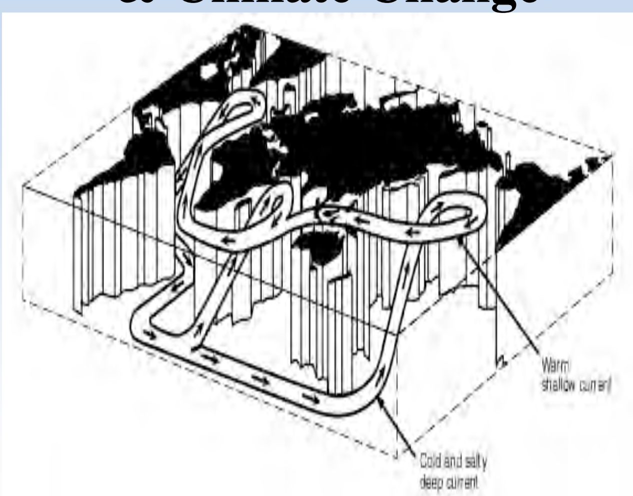
10 km; hours/days

Climate Variability:
El Nino/La Nina
Pacific Decadal Oscillation



100 km; years

Global Conveyor Belt
& Climate Change

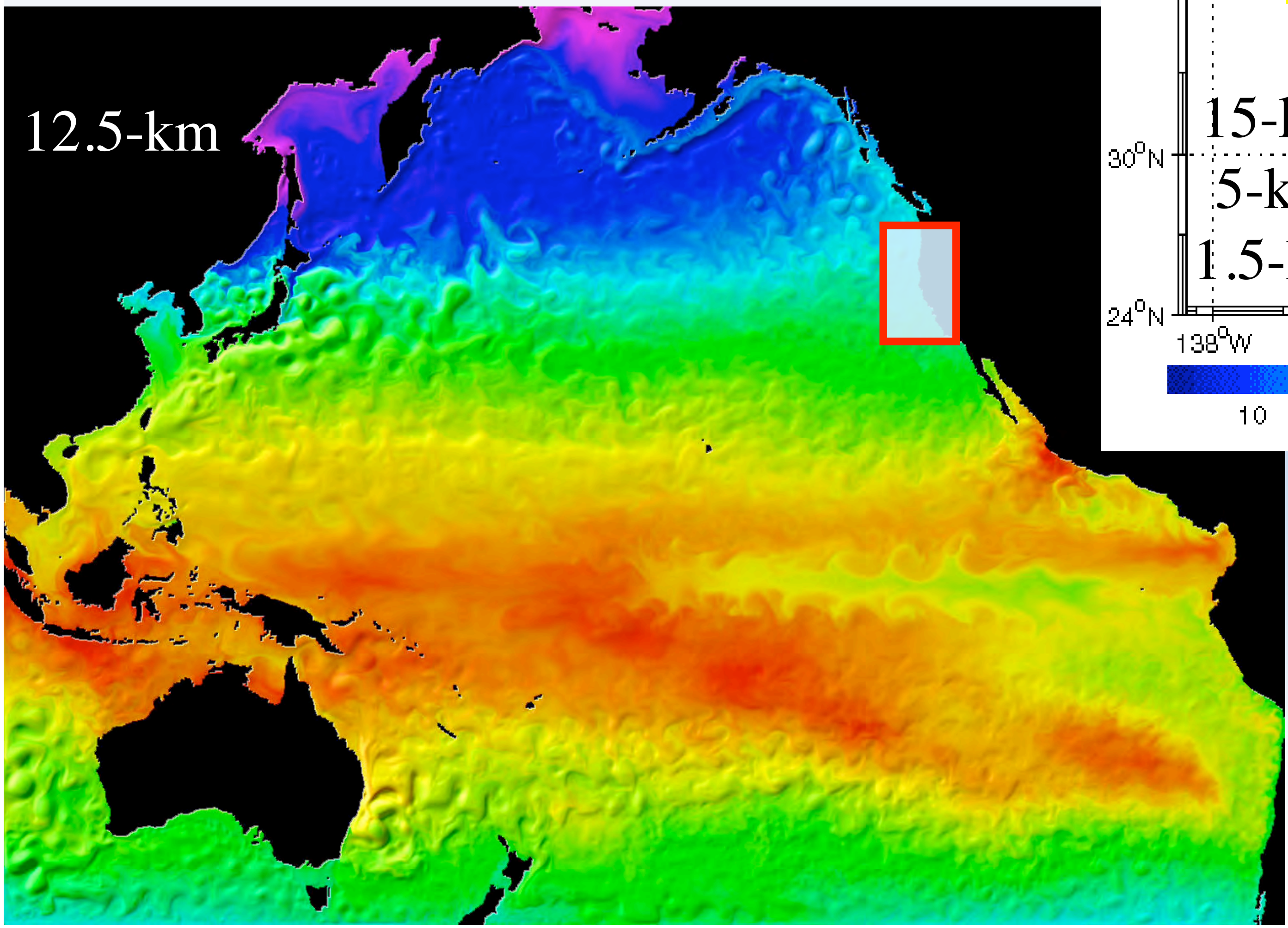


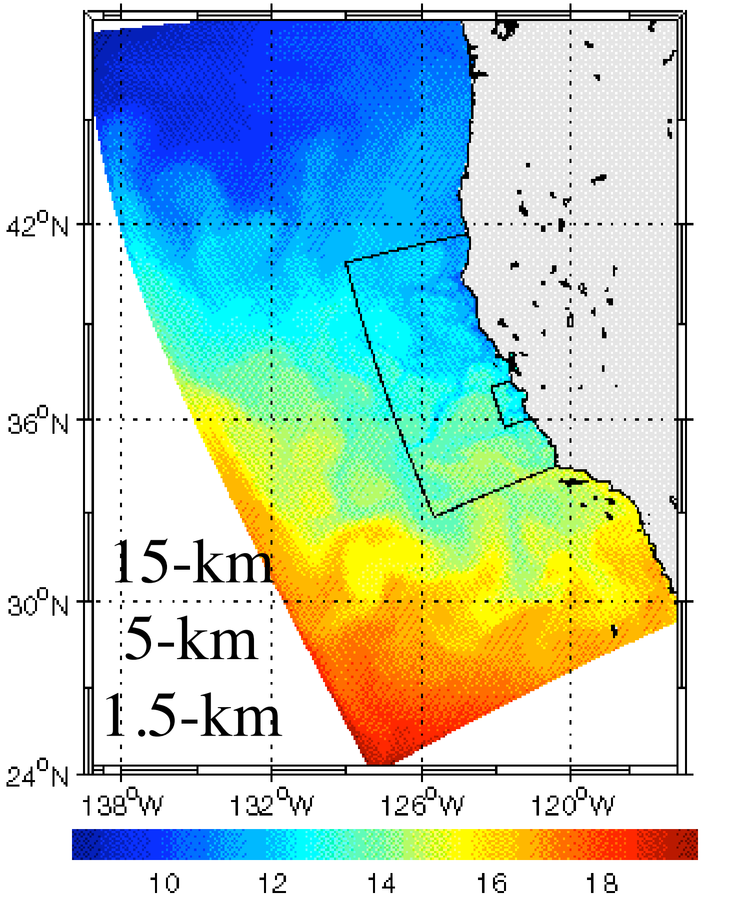
1000 km, decades

Two-Way Interactions

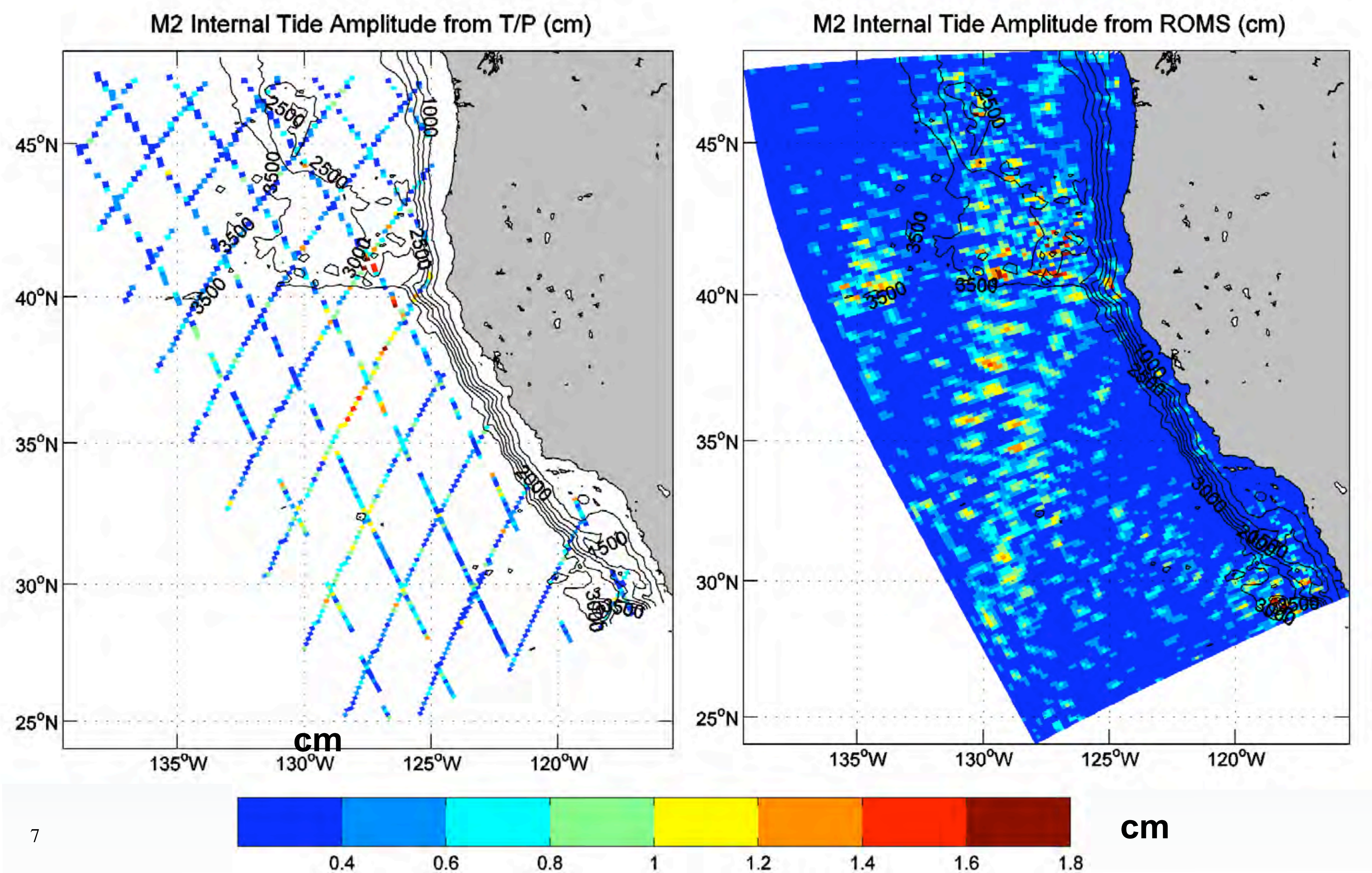
Regional Ocean Modeling System (ROMS)

Multi-scale modeling:
From climate to coastal eddies





Challenge II: Lack of data in coastal zones
Baroclinic Tides (M2) Derived from Altimetry and ROMS



Advanced Data Assimilation: 3DVAR to assimilate in situ and satellite measurements

$$x = \begin{pmatrix} \varsigma \\ u \\ v \\ T \\ S \end{pmatrix} = \begin{pmatrix} x_\varsigma \\ x_{uv} \\ x_{TS} \end{pmatrix} = \begin{pmatrix} x_\varsigma^f + \Pi \delta x_{TS} + \delta x_{a\varsigma} \\ x_{uv}^f + \Gamma \delta x_{TS} + \Phi_a \delta x_{a\psi\chi} \\ x_{TS}^f + \delta x_{TS} \end{pmatrix}$$

Five Control Variables:
Temperature: $\boldsymbol{\delta T}$
Salinity: $\boldsymbol{\delta S}$
Non-steric SSH: $\boldsymbol{\delta X_{a\zeta}}$
Ageostrophic streamfunction: $\boldsymbol{\delta X_{a\psi}}$
Ageostrophic velocity potential: $\boldsymbol{\delta X_{a\chi}}$

$$\delta x_{uv} = \Gamma \delta x_{TS} + \Phi_a \delta x_{a\psi\chi}$$

$\delta x_{uv}^G = \Gamma \delta x_{TS}$ Geostrophic balance

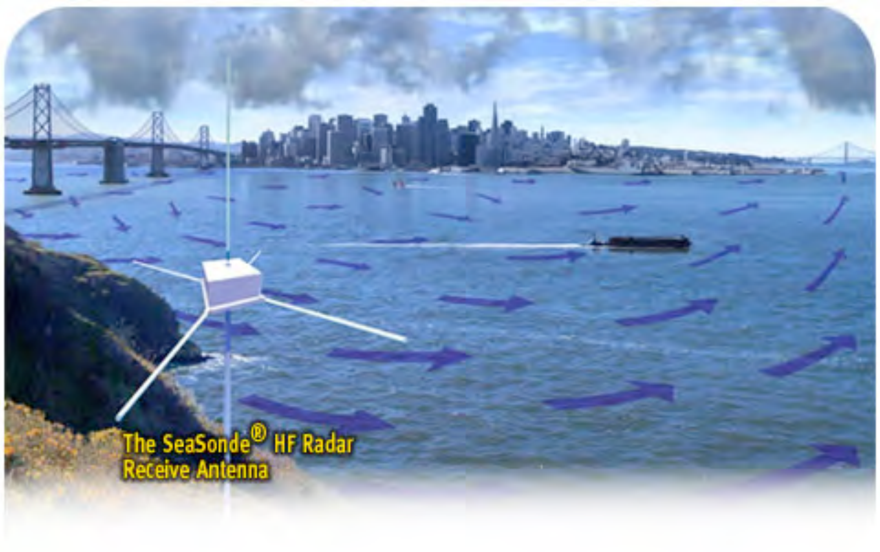
$$\delta x_\zeta = \Pi \delta x_{TS} + \delta x_{a\varsigma}$$

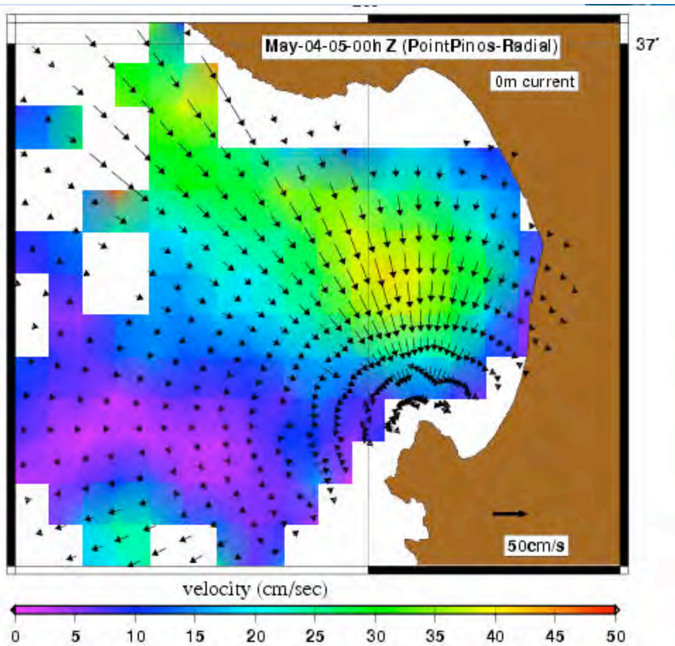
$\delta x_\zeta^S = \Pi \delta x_{TS}$ Vertical integral of the hydrostatic equation

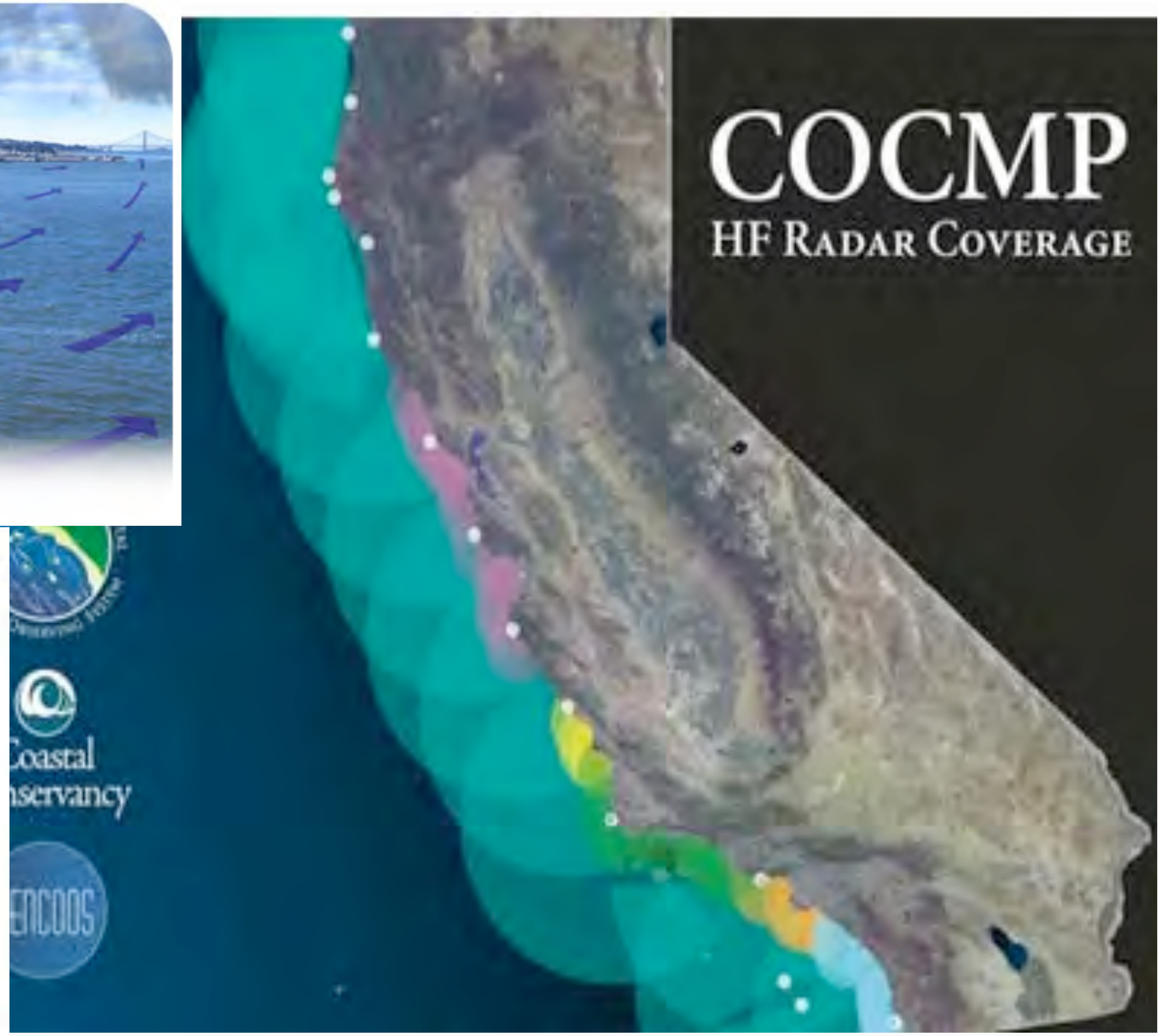
$\delta x_{a\psi\chi}$ ageostrophic streamfunction and velocity potential

(Li and Chao et al., JGR, 2008)

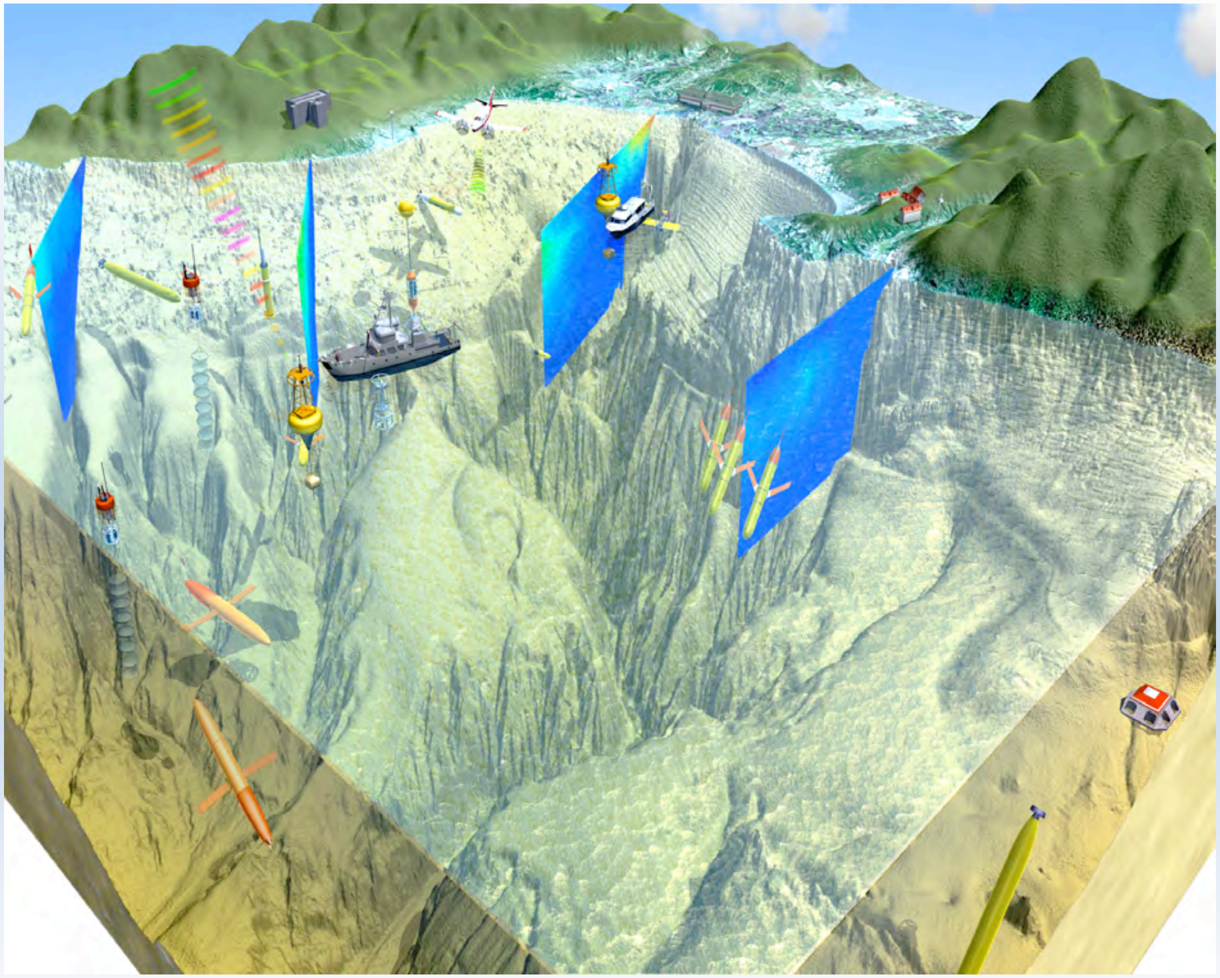
California Coastal Ocean Example
(http://www.cocmp.org)



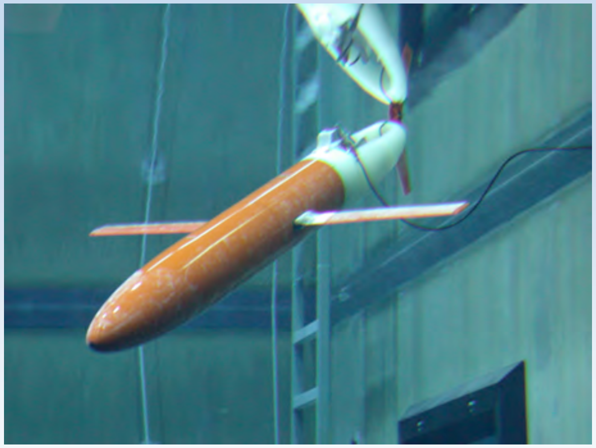




Emerging Autonomous Underwater Vehicle (AUV) glider technology to observe the 3D Ocean

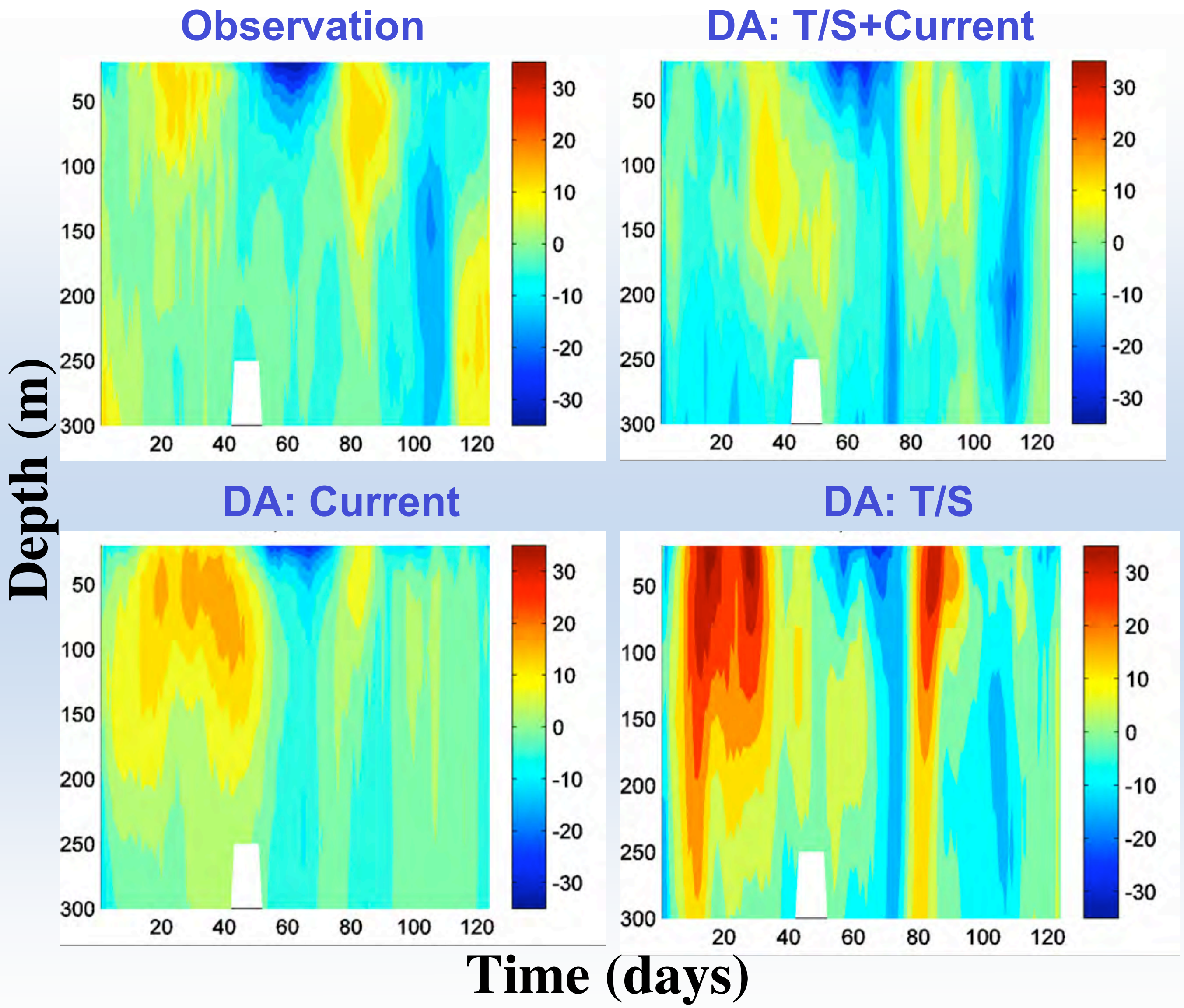


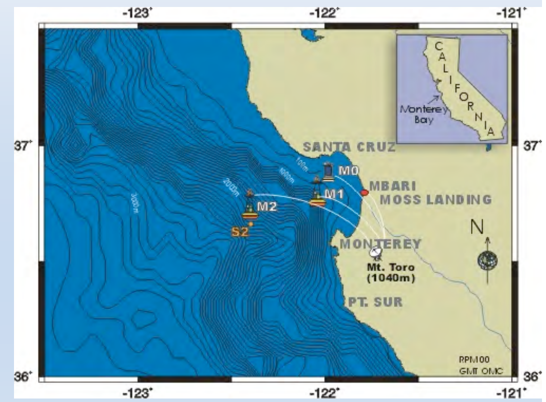
0-200 m Slocums



0-700 m Sprays

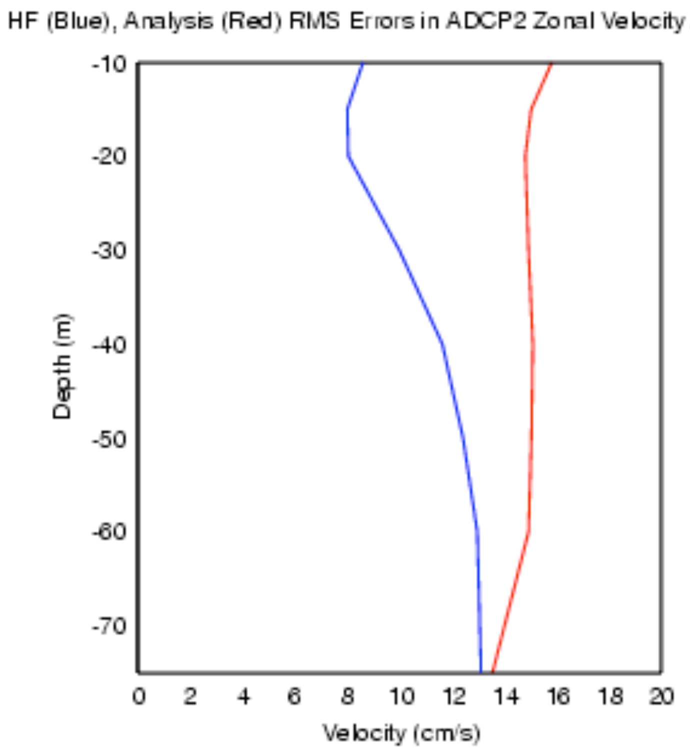
Impact of Ocean Current Assimilation: Independent data validation



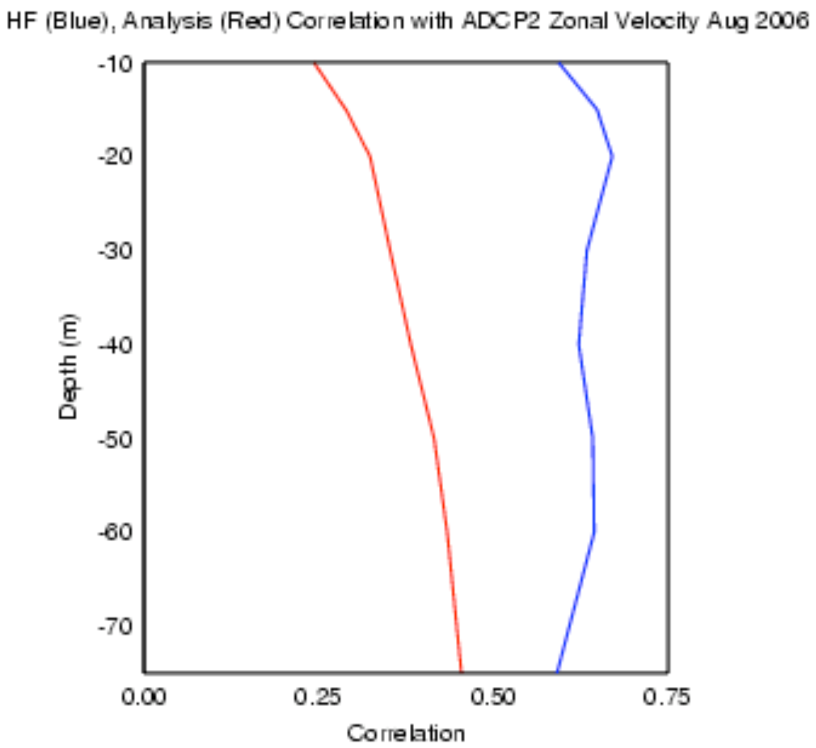


Impact of Surface Current Data Assimilation on Nowcast

RMS



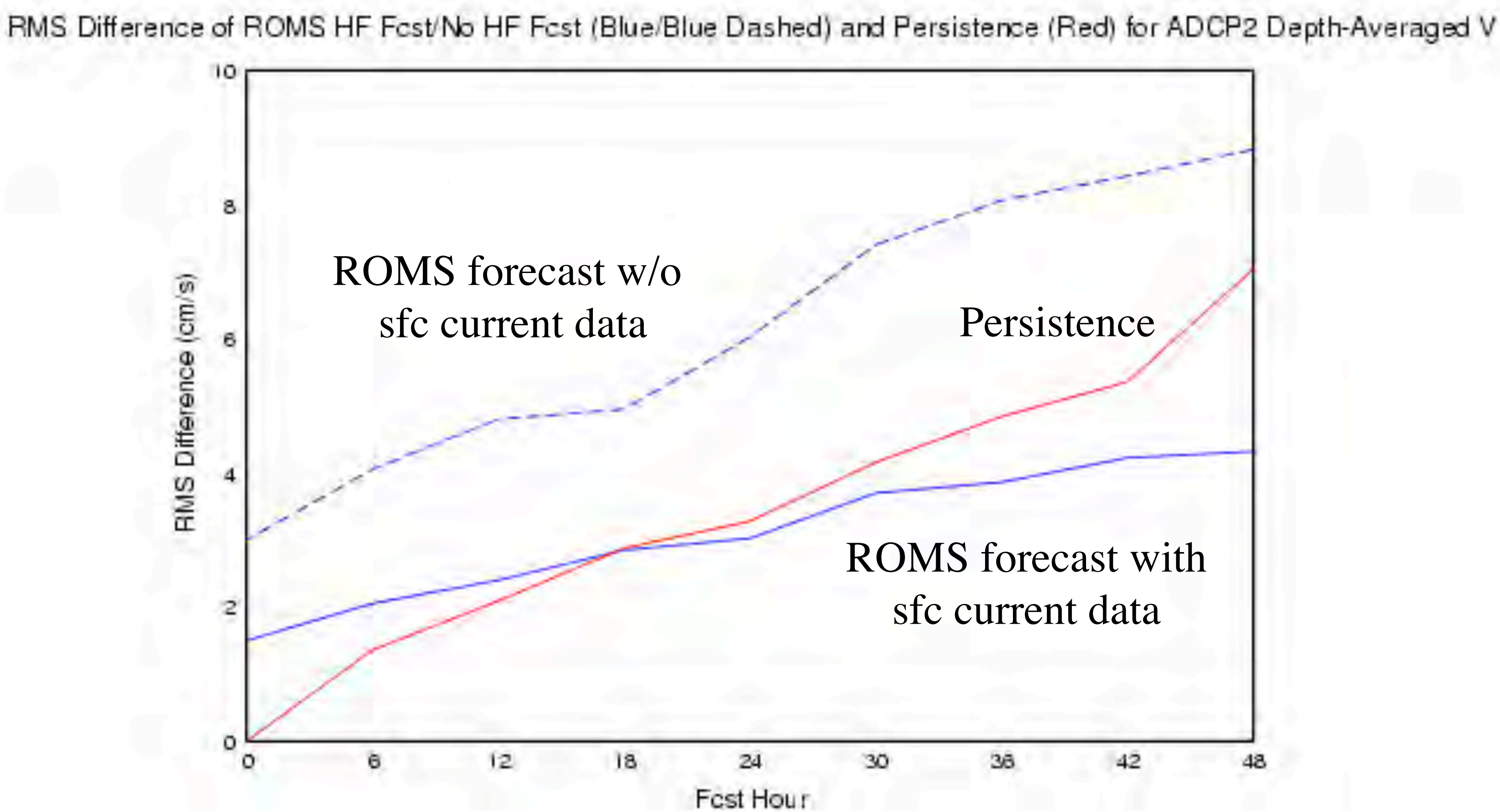
Correlation



ROMS w/o sfc currents

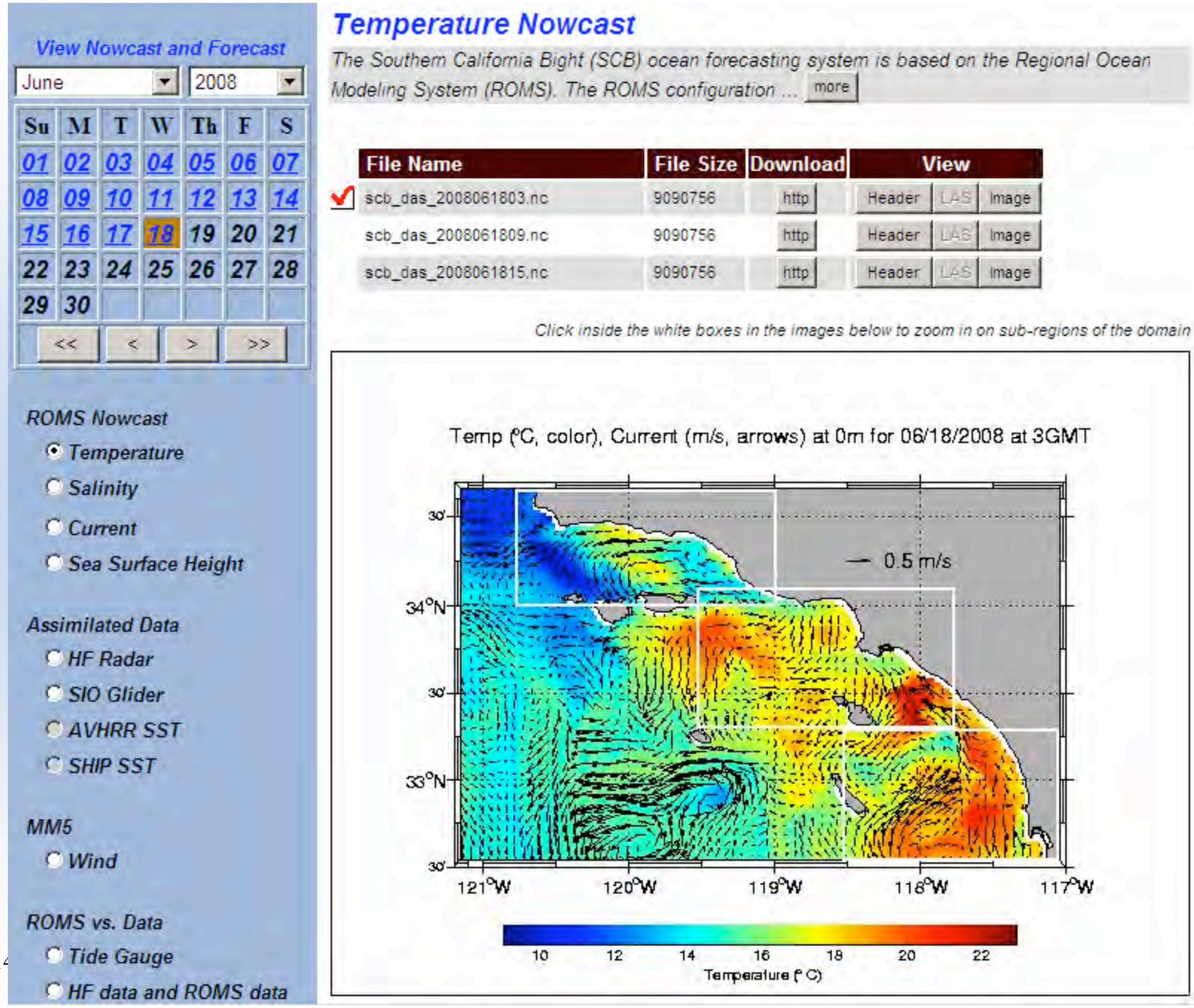
ROMS with sfc currents

Impact of Surface Current Data Assimilation on Forecast

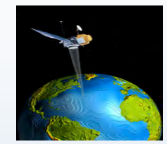


Real-Time Modeling, Data Assimilation and Forecasting

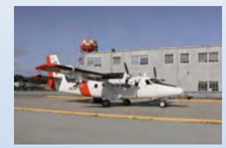
http://ourocean.jpl.nasa.gov/SCB



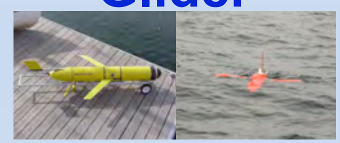
Satellites



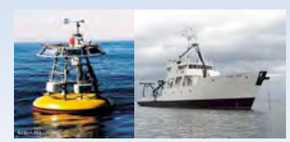
Aircraft



Glider



In-situ



HF Radar

AUV glider is used for data assimilation and verification

http://ourocean.jpl.nasa.gov/SCB

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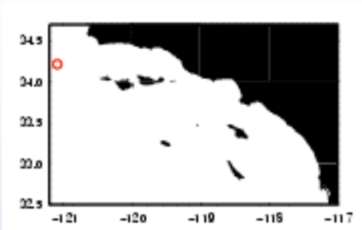

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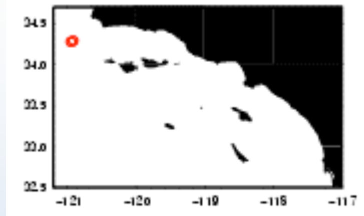

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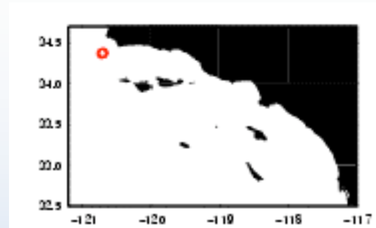

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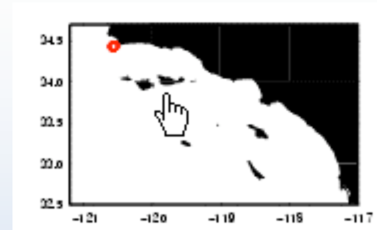

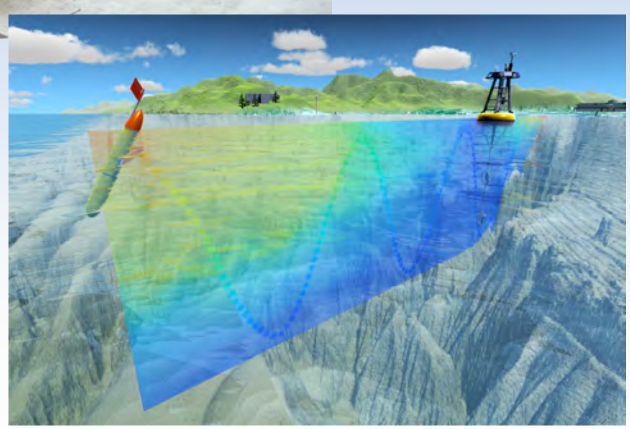

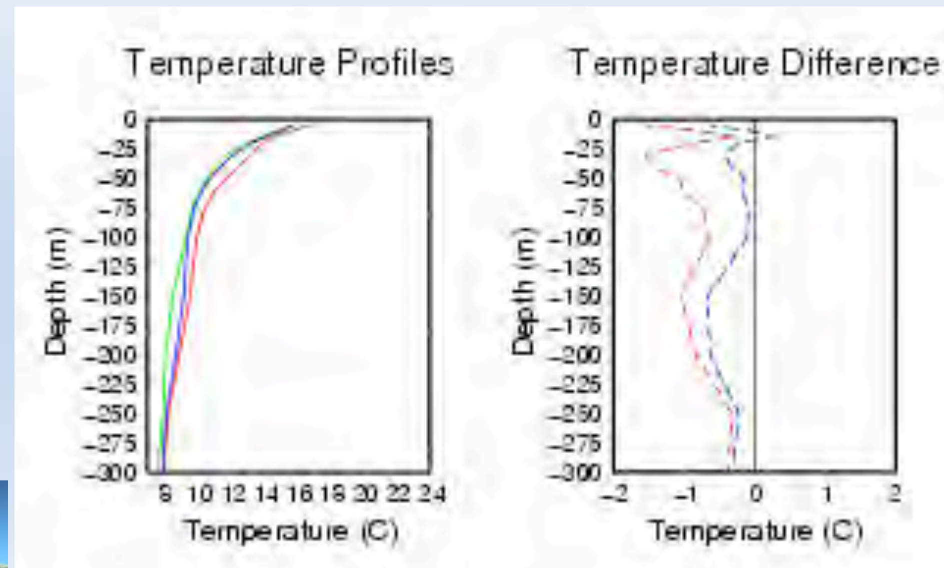

Obs, before & after DA

Coastal Ocean Forecast Customers (and growing) within Southern California

- **Beach goers, surfers**
- **Sailing, fishing, boating**
- **Divers**
- **Marine professionals**

NORTH SAN DIEGO

MORRO BAY

ORANGE COUNTY

SAN DIEGO

Next Generation Altimetry Satellite (SWOT) to enable future ocean forecasting any where & any time to serve broader application users